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Title: Changes in acceleration and deceleration capacity throughout professional soccer match-play

Short title: Acceleration and deceleration in soccer

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ABSTRACT

As the acceleration and deceleration demands of soccer are currently not well understood, this study aimed to profile markers of acceleration and deceleration capacity during professional soccer match-play. This within-player observational study required reserve team players from a Premier League club to wear 10 Hz Global Positioning System units throughout competitive matches played in the 2013/2014 competitive season. Data is presented for players who completed four or more games during the season (n = 11) and variables are presented according to six 15 min intervals (I1-6: 00:00–14:59 min, 15:00-29:59 min, 30:00-44:59 min, 45:00-59:59 min, 60:00-74:59 min, 75:00-89:59 min). During I6, the distance covered (total, per minute, and at high intensity), number of sprints, accelerations (total and high intensity), decelerations (total and high intensity), and impacts were reduced compared to I1 (all $P \leq 0.05$). The number of high intensity impacts remained unchanged throughout match-play ($P > 0.05$). These findings indicate that high intensity actions and markers of acceleration and deceleration capacity are reduced in the last 15 min of the normal duration of match-play. Such information can be used to increase the specificity of training programmes designed for soccer players while also giving further insight in to the effects of 90 min of soccer-specific exercise. Interventions that seek to maintain the acceleration and deceleration capacity of players throughout the full duration of a soccer match warrant investigation.

Key words: Fatigue, football, intermittent, motion analysis

INTRODUCTION

Adaptations to exercise are optimized through progressive manipulation of key variables (including, but not limited to, the volume, intensity and type of exercise stimulus applied) relative to the demands of a sport. As the World's most popular sport, soccer has been extensively characterized (20, 21), primarily with respect to the average distances covered at varying thresholds of speed intensity (6, 17, 18). It is consistently reported that players cover distances of 9–14 km per match (2, 6, 15), with the majority of time spent in low intensity activities such as jogging and walking (3, 18). However, although primarily aerobic in nature (3), high intensity running performance within a game has been found to discriminate between players of differing performance levels (12).

Profiling soccer performance according to speed intensity alone may underestimate a player's true workload during soccer-specific exercise due to a lack of consideration of the energy expenditure associated with acceleration and deceleration (8, 13). This is despite the fact that high intensity running performance has been correlated to fitness status and, as aforementioned, can discriminate between player performance levels (12). Indeed, incorporating acceleration-related workload parameters (e.g., distance covered in specific acceleration/deceleration zones) has highlighted that a 6-8 % difference in exercise load estimation may result from the use of speed versus acceleration-derived monitoring techniques (8, 13). Therefore, quantification of the acceleration and deceleration demands of match-play may provide a further insight into the characteristics of soccer that could inform Sports Scientists and Strength and Conditioning coaches when seeking to improve training specificity and minimize the effects of fatigue during a match.

The number of times that a player accelerates and decelerates during a match could plausibly contribute to the exercise loading, and thus fatigue, experienced during repeated soccer-specific actions. It is therefore surprising that previous authors have tended to report the total time or distance covered in specific acceleration zones (1, 8) as opposed to the number of discrete acceleration and deceleration efforts performed. Bradley et al. (5) highlighted that the number of discrete acceleration (>2.5 $m \cdot s^{-2}$) efforts remained consistent across halves and between the first and last 15 min of elite match-play. Consequently, it was speculated that the transient fatigue patterns observed from analysis of speed intensity data were independent of a player's acceleration capacity (5). Such data contradicts that of Akenhead et al. (1) who identified reductions in specific acceleration parameters of ~15-21 % between the opening and final stages of reserve team match-play. However, it must be noted that key methodological differences between these two studies (e.g., the use of motion analysis versus GPS methods) may have contributed to the lack of agreement.

In summary, the acceleration and deceleration demands of soccer match-play are not fully understood; especially, in relation to the number of efforts performed. Such information is likely to be a factor of interest to Sports Scientists as exercise volume influences transient performance changes throughout match-play and training program design. Therefore, we sought to profile the influence of actual soccer match-play on key markers of physical performance, with a specific focus on the number of acceleration and deceleration efforts, in professional reserve team soccer players. We hypothesized that the demands of match-play would influence physical performance during soccer matches.

METHODS

Experimental approach to the problem

Movement responses were assessed by Global Positioning System (GPS) units worn during 19 competitive matches of the 2013/2014 Under-21 Premier League season. A within-subjects design was used to compare key physical performance variables transiently over 15-min intervals of match-play. This approach is congruent with previous studies in the field (1, 6).

Subjects

A professional under-21 soccer squad competing on behalf of an English Premier League club (highest tier of professional soccer in the UK) was recruited for this study (n = 11; age: 20 ± 1 years; height: 1.8 ± 0.1 m; mass: 70.6 ± 4.3 kg). The study conforms to the Code of Ethics of the World Medical Association (approved by ethics advisory board of Swansea University) and has required players to provide written informed consent prior to participation. All players were considered healthy and injury-free at the time of the study and were in full-time training.

Procedures

All matches were played on outdoor natural grass pitches in accordance with English Football Association rules between November 2013 and April 2014. Before starting the playing season all players had completed a pre-season period of physical and technical preparation that included approximately 10 friendly matches. Following the start of the season, the players training strategy focused upon recovery and maintenance of physiological adaptations and accounted for approximately 10 h per week. Given the observational nature of the study, no attempts were made to influence the player's responses. However, all players performed standardized preparations before each match in agreement with the performance strategy of the club involved. To minimize the effects of variation, only outfield players who completed the full duration of 4 or more games throughout the season were included. Altogether, 76 individual observations of match performance were obtained from 11 players; with 6 ± 4 games being played per player.

Global Positioning System (GPS) analysis

To profile the physical demands of soccer match-play, players wore 10 Hz GPS units (Viper pod, STATSports, Belfast, UK) positioned on the upper torso via a specifically designed vest garment to reduce movement artefacts (9). These devices have been found to perform favourably when compared to other brands of GPS device with a typical error of measurement of <1.7 % being observed throughout a range of soccer-specific activities (technical report available from: http://www.marathoncenter.it/). Units were activated according to the manufacturer's guidelines immediately prior to the pre-match warm-up (~40 minutes before kick-off) and to avoid inter-unit variation players wore the same GPS device for each match. After each match, the raw data files were analyzed and 10 indices of physical performance (Table 1) were derived automatically (Viper PSA software, STATSports, Belfast, UK). Variables presented relate to distance covered (total distance, distance per min, high intensity distance) and the number of sprints, accelerations (total and high intensity), decelerations (total and high intensity) and impacts (total and high intensity) performed.

***** INSERT TABLE 1 NEAR HERE *****

The effects of 90 min of soccer match-play were investigated by dividing the game into six 15 min intervals (i.e., I1: 00:00-14:59 min, I2: 15:00–29:59 min, I3: 30:00–44:59 min, I4: 45:00–59:59 min, I5: 60:00–74:59 min, I6: 75:00–89:59 min). To ensure that the duration of each interval was standardized, data collected in injury time was not included in the analysis.

Statistical analyses

All statistical analyses were conducted using SPSS (Version 19.0; SPSS Inc., Chicago, IL, USA). Results are reported as means and standard deviation (mean ± SD). As per the methods employed by previous studies examining transient changes in performance variables throughout actual match-play (1, 19), between-half changes are assessed using paired samples t-tests and one way repeated measures (within-participants factor: time period) analyses of variance (ANOVA) were used to examine the influence of timing where there were more than two time-points (i.e., every 15-min). Mauchly's test was consulted and Greenhouse–Geisser corrections were applied where the assumption of sphericity was violated. Where appropriate, follow-up analyses were performed using Tukey pairwise multiple comparison procedures. Statistical significance was set at $P < 0.05$.

RESULTS

Between-half analyses identified that distance covered (total and per minute) reduced by 7 ± 6 % (*P* = 0.008) and 8 ± 8 % (*P* = 0.001), from the first to the second halves respectively (Table 1). The total number of accelerations reduced by 9 ± 8 % (*P* = 0.004) in the second half (Table 1) and significant decrements were also observed for the total number of decelerations (9 ± 8 %; *P* = 0.005) and the total number of high intensity decelerations (21 ± 20 %; *P* = 0.002). The total number of impacts were reduced in the second half (11 ± 10 %; *P* = 0.002) whereas trends existed for between-half decrements in the total number of sprints (16 ± 15 %; *P* = 0.052) and the number of high intensity accelerations (15 ± 11 %; *P* = 0.073) performed. The amount of high intensity distance covered and the number of high intensity impacts remained unchanged (*P* > 0.05, Table 2).

********** INSERT TABLE 2 NEAR HERE **********

The total distance covered during I5 and I6 was lower than I1 (13 ± 6 % and 15 ± 10 %, respectively, P < 0.05; Table 3). The distance covered per minute also reduced from 30 min onwards (i.e., I3-I6) when compared to I1 (P < 0.05). High intensity distance covered was reduced at all time points (all P < 0.05) except for I5 (P > 0.05; Table 3). Similarly, the total number of sprints and high intensity accelerations in I6 were 33 ± 29 % (P < 0.05) and 47 ± 25 % (P < 0.05) lower than I1, respectively (Table 3). The total number accelerations were reduced for the final 30 min of each half (i.e., I2, I3, I5, I6) when compared to I1 (all P < 0.05; Table 3) whereas the total number of decelerations was reduced in all time points relative to I1 (all P < 0.05). The number of high intensity decelerations was reduced in I5 (36 ± 22 %) and I6 (40 ± 22 %) when compared to I1 (both P < 0.05; Table 3). The total number of impacts reduced by 18 ± 4 %, 22 ± 6 % and 28 ± 12 % in I4, I5 and I6 respectively (all $P < 0.05$). The total number of high intensity impacts remained unchanged throughout match-play ($P > 0.05$, Table 3).

********** INSERT TABLE 3 NEAR HERE **********

DISCUSSION

In agreement with our hypothesis, we identified transient changes in specific indices of acceleration and deceleration capacity throughout professional Premier League reserve team soccer matches. This is the first study to report data examining the influence of actual soccer match-play on the number of accelerations and decelerations performed by under-21 players in an applied setting. Therefore, such data can be used to inform training programme design with respect to the magnitude and number of acceleration and deceleration efforts performed during a match, and also to give further insight in to the effects of soccer-specific exercise on the physical responses of soccer players.

Second half performance, for the majority of variables analyzed, reduced by 7-21 % (Table 2) and the number of acceleration and deceleration efforts declined in the latter stages of match-play (Table 3). Our findings support, and extend, those previously reported by Akenhead et al. (1) who identified transient changes in the distances covered at specific acceleration and deceleration thresholds in a comparable population of professional reserve team soccer players. Conversely, Bradley et al. (5) reported no changes between halves, and between the first and last 15 min, in the frequency of accelerations observed during elite matches when categorized according to two intensity thresholds (medium: >2.5-4.0 $m{\cdot}s^{-2}$ or high: >4.0 $m{\cdot}s^{-2}$). Although it is plausible that differences in playing status explain the lack of agreement between our data and that of Bradley et al. (5), differences in the methods employed (i.e., the operational definitions used to categorize acceleration thresholds, the use of motion analysis versus GPS techniques etc.) may also limit comparisons.

Notwithstanding the influence of team tactics (22)_ENREF_16, self-pacing strategies (7), and factors specific to the opening phase of a match, such as a desire to enforce tactical superiority (22) and residual ergogenic effects resulting from the warm-up (19), it is plausible that match-related fatigue most likely explains our observations. The mechanisms of match-related fatigue involved in soccer match-play are likely to be multifaceted in origin; nevertheless, compromised fiber-specific muscle glycogen levels (10), dehydration (4), reduced blood glucose levels (4) and factors influencing force development capabilities have been implicated previously (14, 16). Therefore, opportunities exist for the efficacy of interventions that seek to maintain acceleration (e.g., improving sprint technique, concentric strength training and between-leg balance development) and deceleration (e.g., power, reactive strength, dynamic stability and eccentric strength training) capacities throughout the full duration of match-play are warranted.

Although reductions in the number of acceleration and deceleration efforts occurred in the second half (Tables 2), the distance covered at high intensity remained consistent between halves despite this marker demonstrating transient changes throughout match-play (Table 3). Akenhead et al. (1) observed no change in the distances covered at high intensity throughout multiple soccer matches despite other markers of acceleration and deceleration capacity demonstrating transient reductions throughout the second half. A reduction in a player's ability to accelerate in the second half could increase the distance that they are required to cover before a specific speed is reached (1). Providing that distance is not a limiting factor, this could theoretically elevate the high intensity distance covered during the second half despite fatigue effects being observed in other indices of performance and when using the same performance marker over smaller epochs. As such, future researchers may wish to consider the sensitivity of the distance covered at high intensity thresholds to detect transient changes in functional indices of soccer performance.

When interpreting the current findings, a number of limitations should be considered. It is prudent to note that this data does not distinguish between playing positions. Due to the sample of professional players used in this study, data with negligible statistical power would have been yielded if a position-specific approach had been adopted. While acknowledging this limitation, we believe that we present novel findings which support, and extend, previously published data, especially in relation to the transient changes observed (15). Moreover, this study was a descriptive study; therefore, it was not possible to determine the cause of temporal changes in the performance but we acknowledge the potential role of match-specific factors such as game context (e.g., score line, venue, team/opposition quality etc.) (11).

PRACTICAL APPLICATIONS

Characterizing soccer performance according to speed intensity underestimates a player's workload during soccer-specific exercise due to the omission of the energy expenditure associated with acceleration and deceleration (8, 13). Therefore, quantification of the acceleration and deceleration demands of match-play provides further insight into the fatigue-related characteristics of soccer players. Here we present for the first time, data which highlights that participation in reserve team soccer match-play reduces the number of accelerations and decelerations performed as a match progresses. This study provides benchmark data against which the number of accelerations and decelerations performed per match, or during specific intervals of a match, can be compared to. Furthermore, to increase the functional specificity of training, applied practitioners should ensure that soccer players are exposed to movement drills that require similar magnitudes and frequencies of acceleration and deceleration to that reported in this study. Interventions that seek to maintain the capacity for a player to perform accelerations and decelerations throughout the full duration of a match also warrant further investigation.

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TABLE LEGENDS

Table 1: Operational definitions used to define Global Positioning System (GPS) variables

Table 2: Physical performance variables (Mean ± SD) between first and second halves of soccer match-play

Table 3: Mean (with SD in parentheses) physical performance variables as a function of timing throughout soccer match-play

Table 1: Operational definitions used to define Global Positioning System (GPS) variables

Variable	Operational definition
Total distance covered:	Distance covered (m) by all means of locomotion
Distance covered per min:	Total distance covered (m) per min of each interval
High intensity distance covered:	Total distance (m) covered at a velocity >5.5 $m \cdot s^{-1}$.
Total number of sprints:	Count of the number of times a player moved at a velocity >5.5 $m \cdot s^{-1}$ for at least 1 s and maintained a velocity greater than 4.4 $m \cdot s^{-1}$ in the same movement.
Total number of accelerations:	Count of the number of accelerations, where an individual acceleration is defined as an increase in speed for at least 0.5 s that exceeds a maximum acceleration of at least >0.5 $m \cdot s^{-2}$.
Total number of high intensity accelerations:	Count of the number of accelerations that exceed a change in acceleration >3 $m \cdot s^{-2}$ for a period of longer than 0.5 s.
Total number of decelerations:	Count of the number of decelerations, where an individual deceleration is defined as a decrease in speed for at least 0.5 s that exceeds a maximum deceleration of at least >0.5 $m \cdot s^{-2}$.
Total number of high intensity decelerations:	Count of the number of decelerations that exceed a change in deceleration >3 $m \cdot s^{-2}$ for a period of longer than 0.5 s.
Total number of impacts:	Count of the number of impacts, where an individual impact is defined as a maximum accelerometer magnitude value of above 2 G-force units in a 0.1 s period.
Total number of high intensity impacts:	Count of the number of impacts that exceed an accelerometer magnitude value of 9 G-force units in a 0.1 s period.

Table 2: Physical performance variables (Mean ± SD) between first and second halves of soccer match-play.

Variable	Timing		*P* value
	First Half	Second Half	
Total distance covered (m)	4891 (441)	4566 (328)	0.008*
Distance covered (m) per min	107 (10)	99 (7)	0.001 *
High intensity distance covered (m)	261 (102)	226 (100)	0.141
Total number of sprints	14 (5)	12 (5)	0.052 [a]
Total number of accelerations	343 (35)	313 (22)	0.004 *
Total number of high intensity accelerations	14 (5)	12 (4)	0.073 [a]
Total number of decelerations	321 (38)	291 (21)	0.005 *
Total number of high intensity decelerations	24 (7)	19 (6)	0.002 *
Total number of impacts	3271 (845)	2901 (648)	0.002 *
Total number of high intensity impacts	65 (31)	58 (22)	0.174

* Denotes a significant difference between halves at $P \leq 0.01$ level, [a] Denotes a trend for significance between halves at $0.05 > P \leq 0.075$ level

Table 3: Mean (with SD in parentheses) physical performance variables as a function of timing throughout soccer match

Variable	Interval						Time effect (*P* value)	Partial-η^2
	I1	**I2**	**I3**	**I4**	**I5**	**I6**		
Total distance covered (m)	1731 (173)	1592 (150)	1568 (137)	1590 (144)	1513 (118)	1463 (110)	<0.001	0.561
Distance covered (m) per min	113 (11)	106 (10)	102 (10)	103 (8)	97 (8)	96 (6)	<0.001	0.661
High intensity distance covered (m)	99 (32)	79 (41)	83 (33)	72 (39)	83 (33)	70 (33)	0.033	0.270
Total number of sprints	5 (2)	4 (2)	5 (2)	4 (2)	4 (2)	3 (2)	0.004	0.289
Total number of accelerations	122 (14)	112 (11)	109 (14)	114 (11)	102 (6)	97 (9)	<0.001	0.601
Total number of high intensity accelerations	5 (2)	4 (2)	4 (1)	5 (2)	4 (2)	3 (1)	<0.001	0.430
Total number of decelerations	116 (16)	105 (11)	100 (14)	106 (10)	95 (7)	91 (10)	<0.001	0.603
Total number of high intensity decelerations	9 (3)	8 (3)	7 (2)	8 (3)	6 (2)	6 (2)	<0.001	0.539
Total number of impacts	1223 (343)	1043 (259)	1005 (251)	1066 (276)	958 (231)	877 (157)	<0.001	0.659
Total number of high intensity impacts	22 (12)	22 (10)	21 (9)	22 (10)	19 (6)	17 (7)	0.064	0.243

Where I1 = 00:00 – 14:59 min, I2 = 15:00 – 29:59 min, I3 = 30:00 – 44:59 min, I4 = 45:00 – 59:59 min, I5 = 60:00 – 74:5
89:59 min.